A Possible Cause of Earthquakes in the Continental Interior

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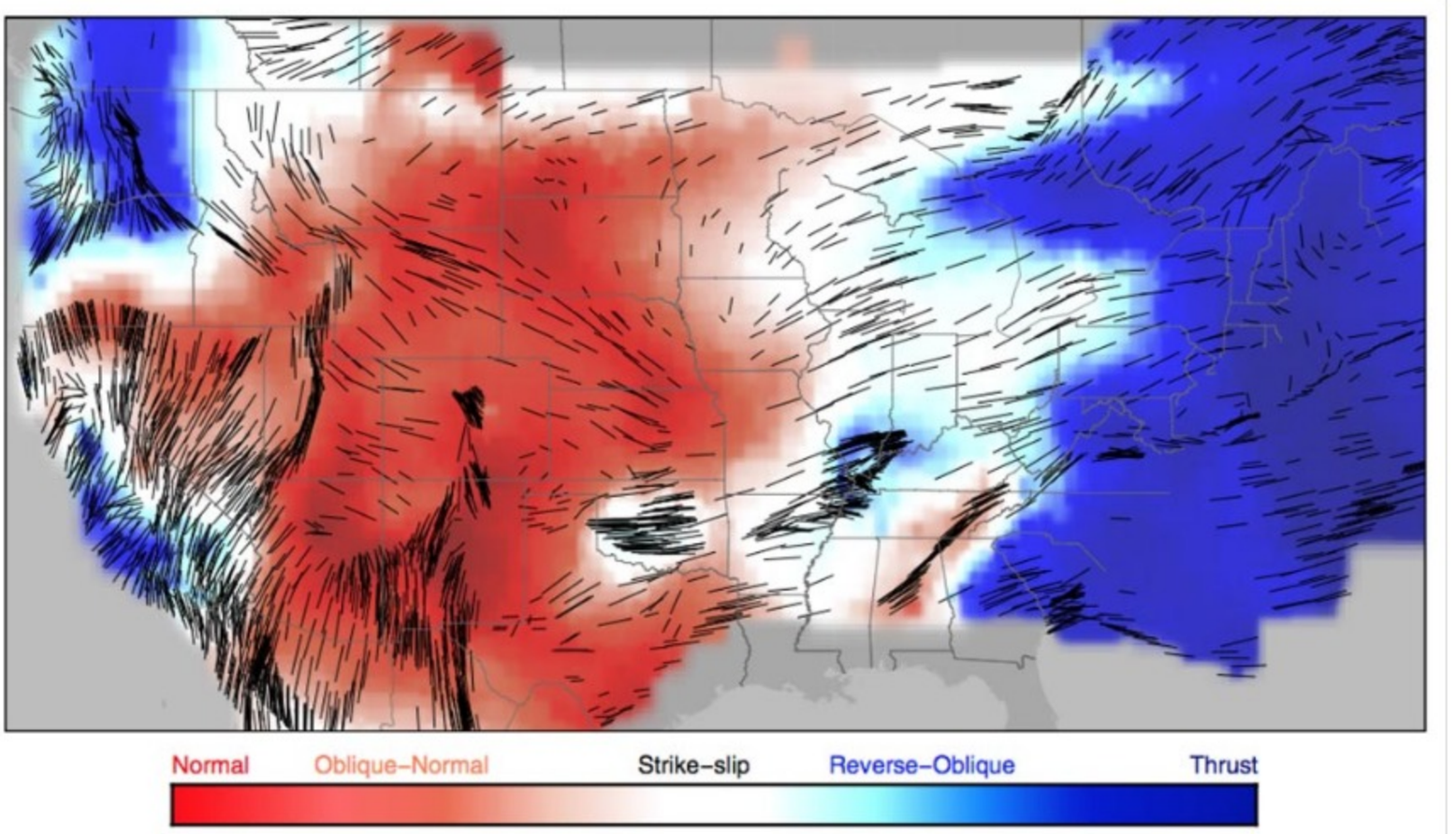
Earthquakes near tectonic plate boundaries are caused by the stress of plate motions. It is less obvious why there are earthquakes in the middle of the plates, far away from plate boundaries. The simplest explanation is that these earthquakes, too, are controlled by the distant plate boundaries; but a new U.S. map of stress in the Earth's crust challenges that idea.

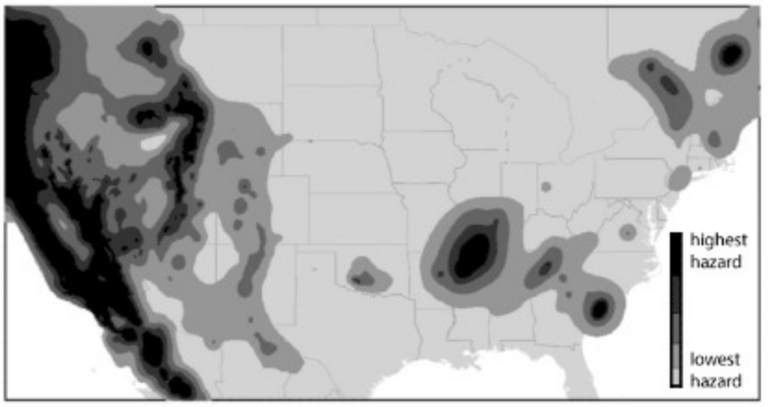
Sketch of plate boundary stress applied to the North American plate.

Researchers took advantage of a large new dataset that they used to analyze earthquakes in the middle part of the U.S., in the deep interior of the North American plate. The new data is available because of both the increase in human-induced earthquakes in parts of the Central U.S. and additional (and better) seismic instruments to record induced and natural seismicity. The nationwide dataset they used included 3,848 earthquakes; 1,966 in the Central U.S. This is 7 times more data than were used in the most recent stress map database.

The scientists determined the direction and style (normal, strike-slip, or thrust) of slip from each earthquake, and by combining many earthquakes, calculated the prevailing crustal stress in that location. The new map of crustal stress across the U.S. shows that the plate interior stress is variable, with contributions from plate boundary stress, crustal collapse due to gravity, and more local and subtle changes to style, orientation, and earthquake rate. These variations appear to reflect persistent stress conditions, existing for millions of years, possibly caused by differences in the crust inherited from long-dead tectonic events including mountain-building and continental rifting.



The new U.S. stress map. The colors show the style of faulting - red is normal faulting, white is strike-slip, and blue is thrust. The black lines show the direction of the stress. The 3 locations in the central U.S. that are different than the areas around them are the regions of highest hazard on the U.S. hazard map (below).



The U.S. hazard map showing the highest hazard areas in black and the lowest hazard areas in gray.

Earthquakes in the central and eastern U.S. tend to cluster in seismic zones rather than being evenly distributed. Most of these highest-hazard zones occur where the local stress patterns differ from the broad, plate-boundary-driven stress. This observation that local stress variations may be the main reason for intracontinental earthquakes helps to explain the zones of higher central and eastern U.S. seismic hazard. However, work remains to define the exact relationship between the local stress and the observed number of annual earthquakes.

These new findings, and increasingly precise stress maps and their relationship with crustal deformation and earthquake rates, will improve our understanding of earthquake hazard and risk by enabling scientists to better map where future earthquakes are more likely to occur.

- written by Lisa Wald, U.S. Geological Survey

For More Information

- Levandowski, W., R.B. Herrmann, R. Briggs, O. Boyd, and R. Gold (2018) An updated stress map of the continental United States reveals heterogeneous intraplate stress, Nature Geoscience, 11, pages 433–437.
- The New Madrid Seismic Zone
- Central Eastern United States - Seismic Source Characterization for Nuclear Facilities
- USGS National Seismic Hazard Map
- Induced Seismicity Research

The Scientists Behind the Science

Will Levandowski.

Will Levandowski (the lead author) was a Mendenhall Postdoctoral Fellow at the USGS Geologic Hazards Science Center in Golden from 2014-2017, where his work focused on seismicity in the Central and Eastern U.S. He likes to climb.